Chapter 6

Public Health Considerations for Drinking Water Supplies

The health effects of contaminants in drinking water are especially important because, as they are ingested, they bring contaminants into intimate contact with the body's interior. In addition, water in fine droplets, such as in showers, may be inhaled and therefore affect the pulmonary system.

6.1 History of Water Treatment

Hippocrates (460 – 354 BC), the father of modern medicine wrote "whoever wishes to investigate medicine properly should … consider the water that the inhabitants use … for water contributes much to health.

The history of water treatment dates back to ancient times. The first constructed sources of drinking water were shallow wells scooped out in wet areas. As tools were developed, deeper wells were constructed such as the ancient Egyptian Joseph's well at Cairo dug to a depth of 297 feet in solid rock. It is two stories, the upper to a depth of 165 feet was 18 feet by 24 feet, and the lower was 132 feet and 9 feet by 15 feet. Water was raised in two lifts by means of buckets on endless chains.

Methods for improving the aesthetic qualities of drinking water were recorded as early as 4000 BC. In addition, there are references in Sanskrit dating back to 2000 BC that refer to boiling and filtering drinking water. Egyptians used alum for clarifying water in the 16th century BC and wick siphons to transfer water from one vessel to another to remove suspended contaminants in the 13th century BC.

These practices seem to indicate that the ancients made a connection between drinking water and health. However, these methods were used for individual homes rather than treating community water systems.

The first community water systems were constructed by Roman engineers to deliver 130 MGD through aqueducts from 343 BC to 225 AD. These aqueducts included settling basins at the headworks and pebble catchers along the aqueduct.

The aqueducts supplied water to only the richest Romans' private taps. Their main function was to supply water to the fountains and reservoirs for the public and for the public baths. Venice utilized rainwater collection systems to channel water from the roofs and courtyards. The water passed through sand filters surrounding the reservoir.

Water treatment was not a concern and did not progress during the Middle Ages. It was not until the 18th century that there was renewed interest in water treatment. Several patents were issued for filtration devices in France and England; however these were for use in private households and on board ships. These filters consisted of charcoal, sponge and wool, much as was described by Hippocrates 2,200 years earlier.

The City of Paisley, Scotland is generally considered as being the first city providing treated water, in1804. It was built by John Gibb to serve his bleachery and the Town and included settling followed by filtration. Three years later this system had expanded to serve customers in Glasgow.

In 1855, Dr. John Snow proved that cholera was transmitted through drinking water by linking an outbreak of the disease in London to the infamous Broad Street well. In the late 1880's Louis Pasteur demonstrated that the "animacules" described by Anton van Leeuvenhoeck 200 years earlier caused illness and could be transmitted through water. By the end of the 19th century most major municipal supplies in Europe had slow sand filtration.

The first filtration system in America was constructed to serve Richmond, Virginia, in 1832. It was not successful, but attempts to make it work were tried for several years. After the civil war (war of Northern aggression) several more attempts were made unsuccessfully.

Slow sand filters constructed in other American cities were also unsuccessful in providing satisfactory water. This was attributed to the sediments in streams in America being essentially different than those in Europe. However, after the civil war, slow sand filtration plants were constructed to improve aesthetic quality in many of the major cities across the U. S.

In 1895, Allen Hazen proved the effectiveness of filtration for removal of microorganisms. In Europe, ozonation was first used as a disinfectant in Nice, France. However, it was too complex and expensive for use in the United States. In 1908, Jersey City, New Jersey started the first continuous chlorination system in the United States. It was based on experience with chlorination in Great Britain where it sharply reduced typhoid deaths. This practice was used across the U.S. and resulted in the virtual elimination of waterborne illness. It succeeded in reducing the death rate from waterborne disease from 25 of 100,000 people annually to virtually none today. These early systems relied on hypochlorites of sodium and calcium. In 1913, liquid chlorine was first used for disinfection in Philadelphia. The chlorination process consisted of bubbling chlorine into the water stream directly from the tank. Leaks were common and costly.

The U.S. Public Health Service published the first federal standards for drinking water in 1914. They established a standard of 2 coliform per 100 ml. While they applied only to drinking water put aboard interstate carriers, many States adopted these standards to apply to all of the public water supplies in the State. The standards were revised in 1925, 1946, and 1962. The 1962 drinking water standards applied to substances and included an Appendix giving the background for the limit for each standard. Most were based on epidemiological evidence from the substances that occurred naturally.

With the advent of manufactured chemicals in the environment and improved analytical methods, concerns were raised about the safety of the drinking water based on the probability of producing cancer as well as long-term toxicity. For the first time, Congress gave a federal agency the ability to promulgate and enforce drinking water standards.

In more recent years, improvements have been made to the coagulation and settling processes. These include the use of polyelectrolytes to form denser and tougher floc, upflow clarification, tube settlers and plate settlers.

Filters have also been improved. Different types of underdrain systems allow filters to be built in many shapes and allow for a more choices in filter media. The filter media can be the traditional silica sand or anthracite. In addition, combinations of these with garnet sand and synthetic media allow for higher filter rates without turbidity breakthrough or loss in filter efficiency.

Ozone is being used more widely, not only for disinfection, but also for oxidation of iron and manganese. New technology for ozone generation developed in Indiana is being used in many States with great success. The new generation of ozone generators operates at lower temperatures and higher efficiency, eliminating the need for expensive materials and complex equipment.

References

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6.2 Health Effects of Drinking Contaminated Water

6.2.1 Biological Contaminants

The early work of Jenner, Snow, Pasteur and others at the start of the 20th century identified several diseases that are transmitted by drinking contaminated water. These included cholera, typhoid and dysentery. As the practice of medicine and identification of disease organisms improved, more diseases were found to be waterborne. These include paratyphoid, amoebic dysentery, hepatitis, polio, giardiasis and gastroenteritis caused by cryptosporidium.

Most waterborne illnesses are transmitted by contamination of the water with fecal material from infected persons or, in the case of giardiasis and cryptosporidium, from infected mammals. If the subsequent treatment is inadequate to remove or inactivate the pathogens, illness can result in the exposed population. With the exception of hepatitis and polio, the health effects include vomiting, diarrhea, and general gastrointestinal upset. This can result in severe distress and death from dehydration.

6.2.2 Chemical Contaminants

Determining the drinking water limits for chemical contaminants has raised many questions over the years. Among these are should limits be set to protect the general public or should they be sufficiently low to also protect people who are more susceptible to the effects of the chemical such as smokers. How do the effects of a chemical in animal studies translate to effects on humans?

The original 28 contaminants were based on epidemiological evidence; however, chemicals added after 1962 have been determined to be toxic based on animal studies sometimes coupled with industrial exposure. The difficulty in establishing standards for these chemicals has been in quantifying the lifetime exposure for people based on short-term, high concentration studies with animals. In addition, it has not yet been determined whether there is a safe limit for cancer producing chemicals below that there are no tumors produced.

As a result, mathematical models based on the animal studies are used as the basis for setting standards. EPA has taken the position in setting these standards that errors should be made on the side of safety.

6.2.2.1 Inorganic Contaminants

Contaminant	Health Effects
Antimony	Decrease longevity and alter blood levels of cholesterol and glucose
Asbestos	Lung tumors
Barium	Damage to the heart and cardiovascular system and associated with high blood pressure
Beryllium	Damage to the bones and lungs with the induction of cancer
Cadmium	Damage to the renal system
Chromium	Damage to the renal system
Copper	High doses can cause stomach and intestinal distress, liver and kidney damage and anemia
Cyanide	Damage the spleen, brain and liver
Fluoride	Dental fluorosis (staining) and skeletal fluorosis (bone damage)
Lead	Interference with blood cell chemistry; abnormal physical and mental development in infants and young children; slight deficits in the atten tion span, hearing and learning abilities of children; and slight increases in blood pressure in adults
Mercury	Damage the renal system
Nitrate	Methemoglobinemia in infants under 6 months
Nitrite	Methemoglobinemia in infants under 6 months
Selenium	Loss of feeling and control in arms and legs
Thallium	Damage the kidneys, liver, brain, and intestines

6.2.2.2 Organic Contaminants

Contaminant	Health Effects
Acrylamide	Cancer and, in large doses, neurological injury
Alachlor	Cancer
Atrazine	Affects the o ffspring in rats and the hearts of dogs
Benzene	Increased risk of leudemia
Benzo(a)pyrene	Cancer
Carbofuran	Damage the nervous and reproductive systems
Carbon tetrachloride	Cancer
Chlordane	Cancer
Dalapon	Damage to the liver and kidneys
1,2-dibromo-3-chloropropane (DBCP)	Cancer
ortho-Dichlorobenzene	Damage to kidneys, liver, blood cells, nervous system and circulatory system
para-Dichlorobenzene	Damage to liver and kidneys
1,2-Dichlorethane	Cancer
1,1-Dichlorethylene	Damage to liver and kidneys
cis-1,2-Dichlorethylene	Damage to liver, nervous system and circulatory system
trans-1,2-Dichlorethylene	Damage to liver, nervous system and circulatory system
Dichloromethate	Cancer
2,4-Dichlorophenoxyacetic Acid	Damage to liver, kidneys and nervous system
1,2-Dichloropropane	Cancer
Di(2-ethylhexyl}adipate	Damage to liver and testes
Di(2-ethylhexyl)phthalate	Cancer
Dinoseb	Damage to thyroid and reproductive system

Contaminant	Health Effects
Diquat	Damage to liver, kidneys, and gastrointestinal tract and cause cataract formation
Endothall	Damage to liver, kidneys, gastrointestinal tract and reproductive system
Endrin	Damage to liver, kidneys and heart
Epichlorohydrin	Cancer
Ethylbenzene	Damage to kidneys, liver and nervous system
Ethylene dibromide	Cancer
Glyphosate	Damage to liver and kidneys
Heptachlor	Cancer
Heptachlor epoxide	Cancer
Hexachlorobenzene	Cancer
Hexachlorocyclopentadiene	Damage to kidneys and stomach
Lindane	Damage to liver, kidneys, nervous system and immune system
Methoxychlor	Damage to liver, kidneys, nervous system and reproductive system
Monochlorobenzene	Damage to liver, kidneys and nervous system
Oxamyl	Damage to kidneys
Pentachlorophenol	Cancer, Damage to liver and kidneys and adverse affects on reproductive system
Picloram	Damage to liver and kidneys
Polychlorinated biphenyls (PCB's)	Cancer
Simazine	Cancer
Styrene	Damage to liver and nervous system
2,3,7,8-Tetrachlorodibenzo-p-dioxin	Cancer
Tetrachloroethylene	Cancer
Toluene	Damage to kidneys, nervous system and circulatory system
Toxaphene	Cancer
1,2,4-Trichlorobenzene	Damage to several organs including the adrenal glands
1,1,1-Trichloroethane	Damage to liver, nervous system and circulatory system
1,1,2-Trichloroethane	Damage to liver and kidneys
Trichloroethylene	Cancer
2,4,5-Trichloro-phenoxy-propionic acid (2,4,5-TP) (Silvex)	Damage to liver, kidneys and nervous system
Vinyl chloride	Cancer
Xylenes	Damage to liver, kidneys and nervous system

6.2.3 Radiological Contaminants

Radiological contaminants cause cancer in due to irradiation of internal organs. Alpha radiation consists of relatively large particles and is normally stopped by the skin. However, when inhaled or ingested, they can affect the organs they contact. The regulated contaminants that emit alpha radiation can be naturally found in groundwater.

Beta radiation is a smaller particle and therefore can penetrate greater distances in the body. The regulated contaminants that emit beta radiation are associated with nuclear power generation and other man-made sources and are generally found in surface supplies.

6.2.4 Physical Contaminants

The only physical primary drinking water standard is turbidity. It has long been recognized that turbidity particles can encapsulate pathogens and protect them from the disinfectants applied. When the particle is ingested, the pathogen is released and can then cause illness. For that reason, the turbidity standard has been lowered for surface water supplies and ground water supplies under the direct influence of surface water.